

## **Swine Manure Nutrient Utilization Project, Crop Year 2002**

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### **Introduction:**

Manure is an important resource for meeting the nutrient needs of corn and soybean grown in Iowa. Land application is the most widely accepted and best economic and agronomic use of manure. Concurrently, however, is the environmental concern when manure nitrogen (N) and phosphorus (P) is not adequately accounted for or utilized by crops. Use of manure as a crop nutrient source requires producer confidence in nutrient availability and maintenance of high crop yields. When that confidence is lacking, either because of unknown application rates or uncertain nutrient content and crop availability, then additional nutrient applications are often made to ensure adequate soil fertility levels. Historically these additional applications are increased manure application rates or additions of fertilizer. This leads to over-application of crop nutrients, reduced profits, and potential for off-site movement and water quality degradation.

On a statewide basis, using 11,820,000 market hogs as an example, there is 88,650,000 lb crop-available N and 95,151,000 lb available P as  $P_2O_5$  produced per year (ISU Pm-1811 – 50% of manure nutrients recoverable and 50% crop available the first year of application). This is a conservative estimate and a large amount of N and P that must be managed well for good crop yield, improved profitability, proper soil resource management, and enhanced water quality.

The overall project goal is to learn more about liquid swine manure N and P availability for corn and soybean production in Iowa and to cause change in manure management practices by crop and livestock farmers. This includes adoption of soil testing, manure nutrient analysis, equipment calibration, agronomic rate application, and following land application best-management practices – so that yearly applications of additional commercial fertilizer can be reduced when appropriate. Specific focus is to demonstrate liquid swine manure application calibration and rate selection, document manure N and P availability to crops, compare crop yield with manure compared to commercial fertilizer, monitor soil and plant nutrient responses to manure application, and evaluate environmental soil tests on manured soils.

The project uses an integrated producer-demonstration-education approach, with coordinated efforts between producers, agronomic extension and research faculty and staff, field agency and extension specialists, and special project coordinators in a series of field demonstrations across Iowa. Information learned from field observation and data analysis will be highlighted at field days and will assist producers with adoption of economic manure and nutrient management practices. This project will also provide information for various manure and nutrient management information sources, educational materials, and education programs.

**Objectives:**

Objectives include: one, work directly with producers and custom applicators to implement field demonstrations and to calibrate manure application equipment or demonstrate state-of-the-art application equipment – to document current application rates and calibration procedures and share with producers appropriate manure application rates based on their manure analysis, calibration, and tractor speed; two, document crop productivity based on manure N and P nutrients and compare to fertilizer sources; three, transfer information to additional producers, landowners, and custom applicators via on-farm demonstrations and field days (including demonstration awareness through field signage) and education programs; and four, update manure management planning information such as nutrient availability and manure nutrient content as data warrants.

**Field Demonstration Description:**

The strategy for this project is to conduct on-farm field demonstrations across Iowa with concurrent data collection to document liquid swine manure N and P availability to crops. Crop yield response to manure is compared with crop yield response to commercial fertilizer. In the first three years of the project (2000-2002) 39 demonstration sites were established with 15 cooperators in 11 counties. Swine manure was applied before corn and soybean crops, and at some sites second-year residual manure nutrient response was monitored.

There are several critical aspects to the demonstration work: 1) calibration of producer and custom applicator manure application equipment; 2) documenting manure analysis; 3) application of replicated manure rate strips across fields by producers or custom manure applicators; 4) placement of replicated fertilizer rates within each manure treatment strip; and 5) collecting soil and plant measurements to substantiate crop availability of manure N and P nutrients. These critical components are required to provide the necessary data and education to move manure management to the desired goal of a recognized and valued nutrient resource – one treated like a fertilizer nutrient source.

Following is an abbreviated listing of the field work plan for the demonstrations: 1) manure application equipment with expected capability to apply agronomic rates and producer willingness to calibrate the manure applicator, or availability of a calibrated commercial manure applicator with electronic flow control equipment; 2) compilation of a production, crop rotation, nutrient application, and soil test history of each field; 3) manure records, pre-application sampling and analysis to set application rates; 4) working with producers, make manure and nutrient applications to the demonstration sites: (a) replicated manure rate strips, including a control with no manure, and (b) replicated fertilizer N and P rates applied to small areas within each manure application strip; 5) collect samples for routine soil and environmental N and P tests, plant N and P tests, grain yield, and color aerial images; and 6) study residual manure effects to the next crop in rotation.

## Project Activity:

Major activities are identification of project cooperators, location of field demonstration sites, pre-application manure sampling, soil sampling, liquid swine manure application, manure sampling, fertilizer application, and grain harvest.

Eight field demonstration sites were identified in 2000, with 16 demonstration sites in both 2001 and 2002 (Figure 1). All sites utilized liquid swine manure. Manure at each site was from under-building pit storage, with the exception of two sites with outdoor concrete tank storage. Of eight new 2002 demonstration sites, only the Davis County site had manure applied in spring 2002; seven new 2002 demonstration sites had manure applied in November 2001.

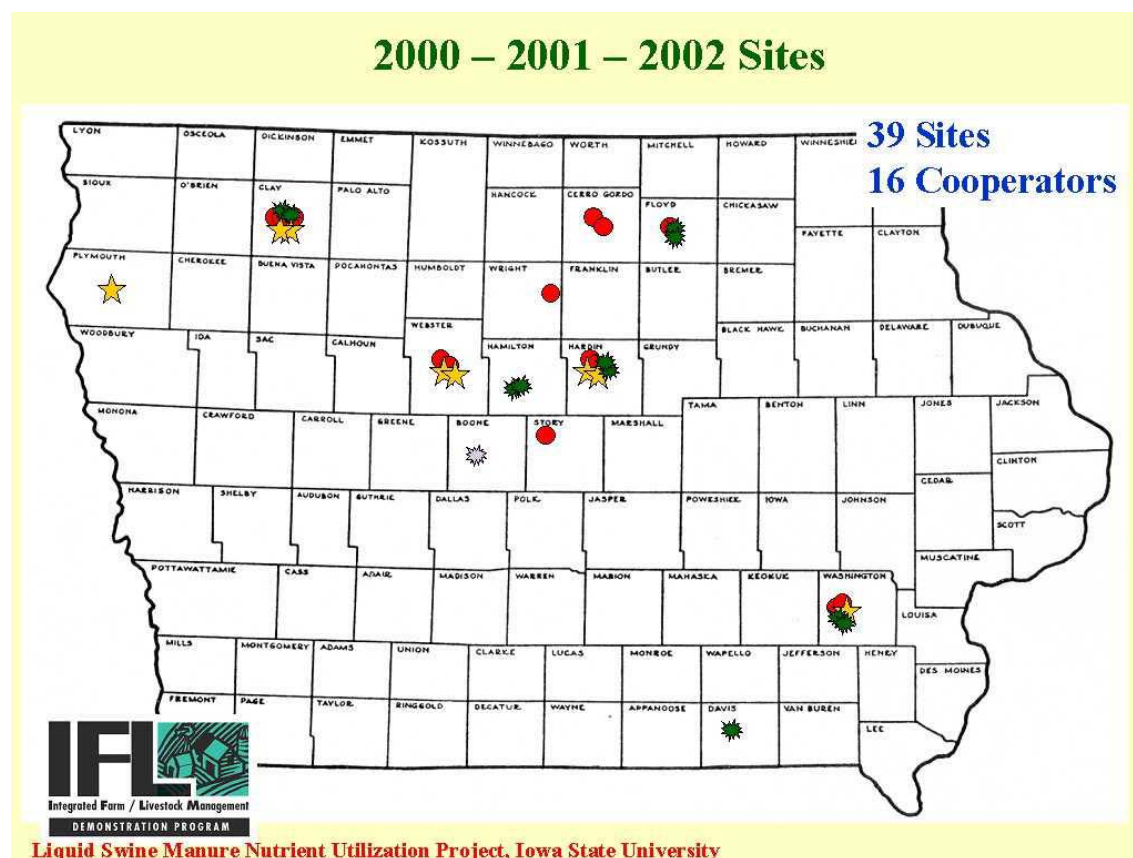


Figure 1. Swine manure nutrient utilization project field demonstration sites, 2000-2002. Stars represent locations of 200 field sites, circles represent 2001 field sites, and splashes represent 2002 field sites.

Manure application equipment was calibrated at application. At some locations applicators were equipped with an electronic flow monitor and rate controller, which aided application and rate uniformity. Manure was injected at all new 2002 sites. Multiple manure samples are collected during application. These are analyzed for total-N, ammonium, total-P, total potassium (K), and solids. At each site cooperators are asked to not apply manure or fertilizer to the site area, other than manure strips. All other field activities are completed as normal by the cooperator, including grain harvest of the application strips.

### Manure demonstration rates and fertilizer applications for corn

Three manure application strips across the field length (replicated three times): check – with no manure, fertilizer N, or fertilizer P; low – manure at rate to supply approximately half corn N need (75 lb total-N/acre); and high – manure at rate to supply approximately full corn N need (150 lb total-N/acre). These rates are for corn following soybean, and are intended to supply adequate manure N and less-than-adequate manure N. The assumption is made that all of the swine manure N is first-year crop available. The individual manure strip widths match a multiple of the manure applicator width and combine header width.

Fertilizer N application is hand-applied to small plots within each manure application strip: superimpose four randomized small plot fertilizer N rates on each manure and control strip: 0, 40, 80, 120 lb N/acre (Figure 2). Fertilizer N rates are broadcast applied by hand to the soil surface in the spring immediately after corn planting. The N source is ammonium nitrate. A blanket application of P (60 lb P<sub>2</sub>O<sub>5</sub>/acre) and K (60 lb K<sub>2</sub>O/acre) fertilizer is made to the small N plots in order to mask the effect of these nutrients applied in the manure.

Figure 2. Example demonstration plot layout, with replicated small N and P fertilizer plot locations superimposed on replicated manure treatment strips.

1/2 Manure Rate		Check		Full Manure Rate		Check		Full Manure Rate		1/2 Manure Rate		Full Manure Rate		1/2 Manure Rate		Check	
N-1	N-4	N-4	N-3	N-3	N-1	N-4	N-1	N-1	N-2	N-1	N-3	N-3	N-2	N-3	N-4	N-3	N-4
N-2	N-3	N-1	N-2	N-2	N-4	N-3	N-2	N-4	N-3	N-4	N-2	N-4	N-1	N-2	N-1	N-2	N-1
P-2	P-1	P-4	P-3	P-1	P-4	P-1	P-2	P-2	P-1	P-4	P-1	P-4	P-3	P-1	P-2	P-1	P-3
P-3	P-4	P-2	P-1	P-2	P-3	P-4	P-3	P-4	P-3	P-3	P-2	P-1	P-2	P-3	P-4	P-2	P-4
Replication 1						Replication 2						Replication 3					

Fertilizer P application is hand-applied to small plots within each manure application strip (usually only at those sites with optimum to very low soil P tests): superimpose four randomized fertilizer P rates on each manure and control strip: 0, 20, 40, 60 lb P<sub>2</sub>O<sub>5</sub>/acre. These are broadcast applied

by hand and incorporated with secondary tillage. The P source is triple superphosphate. A blanket application of N (150 lb N/acre) and K (60 lb K<sub>2</sub>O/acre) fertilizer is made to the small P plots in order to mask the effect of these nutrients applied in the manure.

At some sites manure rates were based on intended P application or other intended N rates. For example, at a continuous corn site, rates might be at 100 and 200 lb total-N/acre.

#### Manure demonstration rates and fertilizer applications for soybean

Three manure application strips across the field length (replicated three times): check – with no manure, fertilizer N, or fertilizer P; low – manure at rate to supply approximately half soybean grain N removal (100 lb total-N/acre); and high – manure at rate to supply approximately full soybean grain N removal (200 lb total-N/acre). The assumption is made that all of the swine manure N is first-year crop available. The individual manure strip widths match a multiple of the combine header width.

Fertilizer P application is hand-applied to small plots within each manure application strip (usually only at those sites with optimum to very low soil P tests): superimpose four randomized fertilizer P rates on each manure and control strip: 0, 20, 40, 60 lb P<sub>2</sub>O<sub>5</sub>/acre. These are broadcast applied by hand and incorporated with secondary tillage. The P source is triple superphosphate. A blanket application of K (60 lb K<sub>2</sub>O/acre) fertilizer is made to the small P plots in order to mask the effect of this nutrient applied in the manure.

#### Soil and plant sampling

The overall project soil and plant sampling and analyses includes the following: collect initial soil samples for routine analyses before manure application, sample small corn and soybean plants and determine plant weight and P content, collect late spring nitrate test and other soil N test samples, take Minolta® 502 SPAD chlorophyll meter readings from corn ear leaves at the R1 growth stage (silking stage) to monitor N response through leaf greenness, harvest manure strips and small plots for grain yield, collect end-of-season cornstalk samples, fall soil samples, and post-harvest profile soil nitrate samples, and analyze soil samples for routine soil tests, soil N tests, and environmental P tests.

Results of preliminary 0-6 inch surface soil samples collected before manure application at 2000-2002 field sites are presented in Tables 1 and 2. Some plant and post-harvest soil test samples are still being analyzed, and are not reported in the 2002 small-plot data summary Appendix Tables.

Grain yield is determined for each manure strip by combine harvest and for each small N and P fertilizer small plot by hand harvest of measured areas, with corn yields adjusted to 15.5% grain moisture and soybean yields adjusted to 13% grain moisture. Seed protein, oil, and starch are determined by near-infrared spectroscopy (NIR) analysis.

Table 1. Routine soil test averages for 0-6 inch surface soil samples collected from field-length strips before manure application, 2000-2002.

Site-Year	Soil Test P (Bray-1)	Soil Test K (Ammon. acetate)	pH	Organic Matter
	----- ppm -----			%
<u>2000</u>				
Webster	17	133	6.6	5.7
Clay	44	220	5.8	6.8
Hardin	104	269	6.4	5.8
Washington	"Very High"	"High"	--	--
Plymouth	45	228	6.0	3.7
<u>2001</u>				
Cerro Gordo	19	222	5.8	4.3
Clay	7	171	5.8	5.9
Washington	48	216	7.0	6.1
Wright	34	212	6.5	4.9
Hardin	27	147	6.6	4.8
Story	16	114	6.3	3.9
Hardin (c-c) <sup>‡</sup>	27	117	7.3	5.6
Cerro Gordo (c-c) <sup>‡</sup>	25	186	6.7	6.4
Floyd (alf-c) <sup>§</sup>	15	114	6.7	5.6
Clay (residual) <sup>¶</sup>	--	--	--	--
Webster (residual) <sup>¶</sup>	--	--	--	--
<u>2002</u>				
Davis	13	85	7.1	3.4
Hamilton	19	186	7.0	6.5
Washington	122	219	6.7	5.1
Hardin	38	161	6.5	5.2
Hardin (c-c) <sup>‡</sup>	--	--	--	--
Clay (residual) <sup>¶</sup>	--	--	--	--
Washington (residual) <sup>¶</sup>	--	--	--	--

<sup>‡</sup> Sites where corn followed corn. Hardin site in 2002 was second year with manure treatment application (same site as 2001).

<sup>§</sup> Site where corn followed alfalfa.

<sup>¶</sup> Sites where manure was applied before the previous-year soybean crop. No manure applied the year corn was grown.

Table 2. Routine soil test averages for 0-6 inch surface soil samples collected from field-length strips before manure application, 2000-2002.

Site-Year	Soil Test P (Bray-1)	Soil Test K (Ammon. acetate)	pH	Organic Matter
	----- ppm -----			%
<u>2000</u>				
Clay	30	198	6.1	6.0
Webster	29	168	6.5	5.6
Hardin	113	232	5.7	4.9
<u>2001</u>				
Clay	10	170	6.2	5.9
Washington	17	194	6.5	4.7
<u>2002</u>				
Floyd	19	98	6.7	3.8
Hamilton	21	98	6.0	3.6
Washington	42	238	6.6	6.1

### **Preliminary 2000-2002 Results:**

#### *Field Manure Application (Calibration and Sampling)*

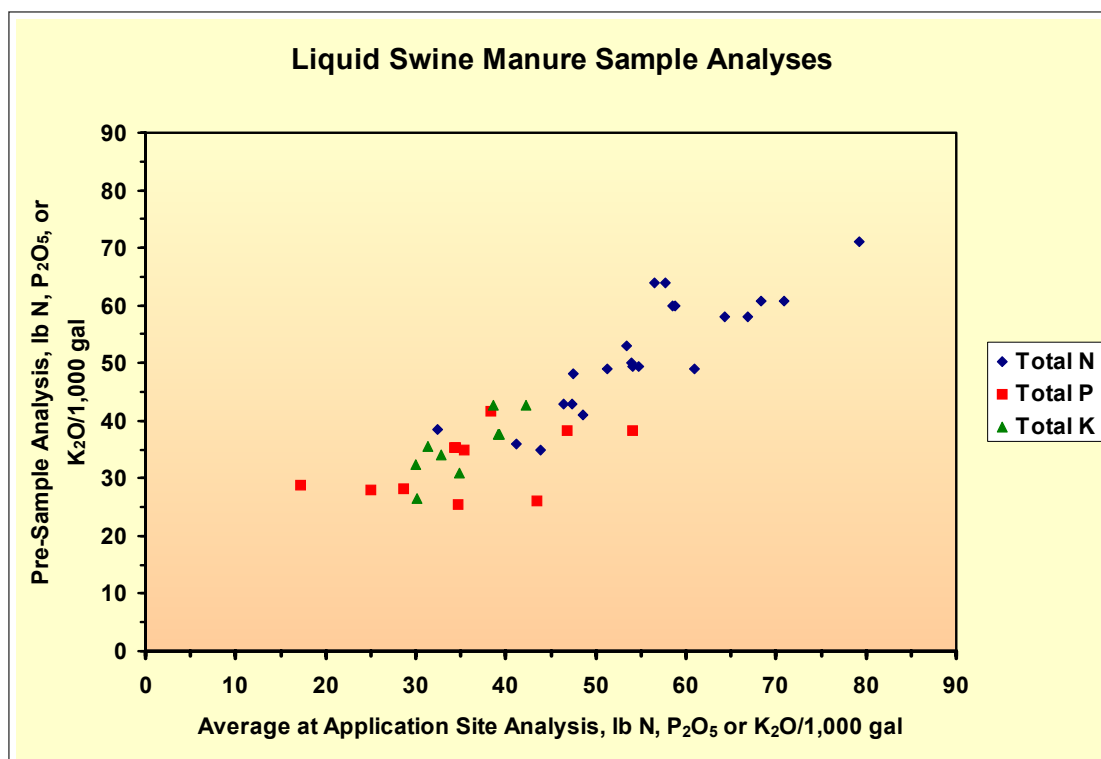
An important component of the demonstration project is increasing producer awareness of the importance of manure sampling to estimate total nutrient content. At all 2000, 2001, and 2002 demonstration sites (representing 54 manure treatment applications) pre-application manure samples were collected for determination of total-N or total-P<sub>2</sub>O<sub>5</sub>/1000 gallons manure; once determined, the total-N or P nutrient concentrations were used to calculate agronomic manure application rates for each demonstration site (Appendix Tables 1-3). The results of pre-sampling and sampling during application highlight the consistency of manure total nutrient concentrations within a single manure source, and the ability of pre-sampling to successfully guide application rates. Manure nutrient concentrations varied considerably between sites, indicating the need for manure analysis history and pre-application sample analysis, and indicating the improvement in setting application rates with actual analyses instead of using tabled (book) values. In conjunction with applicator calibration (through use of weigh pads and application over measured areas), intended rates were achieved with good consistency.

#### *Pre-Application Manure Analyses Compared with At-Application Analyses*

For all sites, the manure source was from swine finishing facilities with storage in under-building pits or outside concrete tanks (two sites). Manure samples were collected 2 to 3 weeks before planned application by either dipping manure off the surface or probing the storage profile. Forty of the 54 applications were based on total-N, with the remaining 14 based on total-P. Multiple samples (up to 11 samples per site) were collected during application to the demonstration sites (98 total manure samples for the 3 years). Manure was agitated during pump-out of the storage structures. Figure 3 shows a comparison between the pre-application sample analyses (total-N,

P<sub>2</sub>O<sub>5</sub>, or K<sub>2</sub>O per 1,000 gallons) and the average of the samples per site collected during application. Pre-samples were often analyzed only for total-N if the application was to be based on total-N. Figure 3 represents the ability of the pre-sample to predict the manure nutrient concentration during application. Overall, the pre-sample gave a good prediction of the total-N concentration expected during application. On average, the pre-application sample had 5.7 percent lower total-N than the at-application samples. Across all sites, the average ammonia-N in the liquid swine manure was 83 percent of the total-N. For P, the variation between pre- and at-application sampling was larger, but in some instances the pre-sample was dipped off the manure surface, which is not expected to provide a good representation of P in an agitated pit. Because potassium (K) is contained in the soluble manure solution, the pre-application samples were close to the at-application samples.

Figure 3. Comparison of pre- and at-application liquid swine manure nutrient analyses.

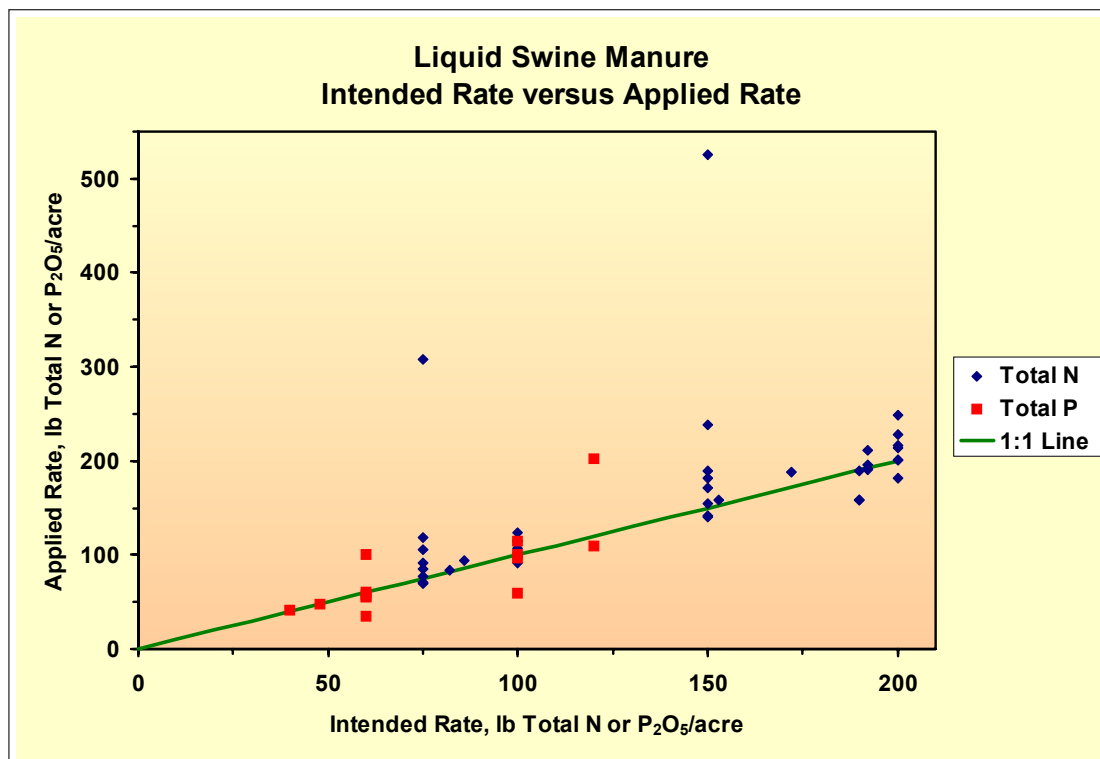


#### Intended Manure Nutrient Rate Compared with Calculated Applied Rate

Figure 4 shows the comparison of the intended manure total-N or total-P application rate and the calculated applied nutrient rate. The applied rate was calculated from the average analyses of the manure samples collected during application at each site and the application equipment calibration. For total-N, if one accepts  $\pm 30$  pounds N/acre as an acceptable ability to apply manure-N, then 18 percent of the applications (7 of 40 applications) were outside this range (all but one of these was with a vacuum style applicator). In some instances, the calibration process indicated that greater than desired rates were going to be applied because of equipment limitations to reduce the flow rate and/or tractor speed limitations. These sites were kept in Figure 4, and an example is the two very high application rates. The occurrence of applications well above intended rates happened with vacuum-style applicators, and especially when the manure nutrient

concentration was high. For total-P, if one accepts  $\pm 15$  pounds  $P_2O_5$ /acre as an acceptable ability to apply manure-P, then 29 percent of the applications (4 of 14 applications) were outside this range, mainly due to the pre-sample P analysis being higher or lower than the at-application samples. However, a wider range in P application could be expected as some of the manure samples were dipped from the manure storage surface for total-N measurement rather than probed, which would be expected to not represent P as well.

Figure 4. Comparison of intended and calculated as-applied liquid swine manure nutrient application rates.



When based on either total-N or total-P, 19 percent of applications were greater than 25 percent from the intended rate (10 of 54 applications). The majority of applications were within 15 percent of the intended rate. If you take out the two known high application rates from one site, then 13 percent of applications fall outside the  $\pm 30$  lb total-N/acre range. Seven of the 10 high application rates were made with vacuum-style equipment. Many of the applicators used in the project were equipped with a flow monitor and rate controller. These applicators calibrated well, and variation between intended and calculated rates generally were due to differences in the pre- and at-application manure analyses. Partly due to the pre-application sample analysis being lower than the at-application sample, the tendency was for the calculated applied rate to be larger than the intended rate.

#### *Variability in Nutrient Analyses for Samples Collected During Application*

Figure 5 shows the comparison of individual manure sample N, P, and K analyses and the site average analyses. Because the project worked with producers from a wide area of Iowa and with different swine production practices, one would expect a wide range in total-N, P, and K content, as is seen with the distribution in average site analyses. For total-N, the lowest site had 32 pounds and the highest site had 79 pounds total-N/1,000 gallons. For total-P, the lowest site was 17 and

the highest 54 pounds  $P_2O_5$ /1,000 gallons. For total-K, the lowest site was 23 and the highest 48 pounds  $K_2O$ /1,000 gallons. These differences in site averages highlight the importance of sampling and laboratory analysis rather than using book values. Only if a book value happens to coincide with the actual analysis would the book value be helpful for determining application rates.

Figure 5. Variability in average liquid swine manure nutrient analyses between demonstration sites and within multiple samples collected during application.

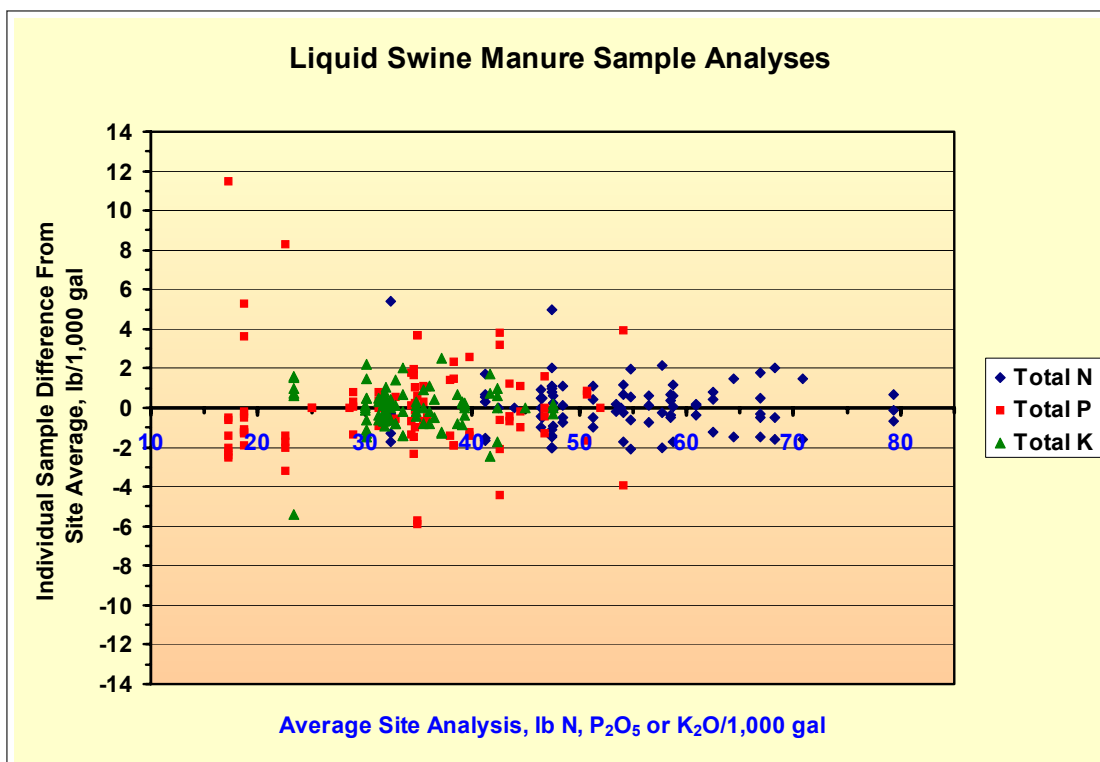


Figure 5 also shows the variation within the multiple samples collected during each application. For N and  $K_2O$ , the ranges are very narrow, with most samples falling within  $\pm 2$  pound/1,000 gallons (94 of 98 samples within this range for N and K). For P the variation was wider (22 of 98 samples greater than  $\pm 2$  pounds  $P_2O_5$ /1,000 gallons), indicating the tie between P and variation in solids content as a storage structure is emptied.

In summary, the project is documenting the importance of sampling liquid swine manure for determining nutrient concentrations. In conjunction with application equipment calibration, manure pre-application analyses are helpful for achieving desired nutrient application rates. The entire application process requires effort, but can be successful if careful attention is paid to sampling, calibration, and rate monitoring and control. In addition, over time a manure analysis history from the pre- and at-application samples can be developed that will aid future applications and reduce the reliance on pre-application samples.

### *Yield and Associated Plant Growth Measurement Response to Swine Manure and N Fertilizer*

Corn grain yield level and yield response to liquid swine manure application and additional N fertilizer varied by site in 2000-2002 (Tables 3 and 4). Low- and high-rate manure applications substantially increased average corn strip yields relative to the no-manure check at 15 of 17 first-year manure evaluation sites in 2000-2002. Of the total yield increase to manure application, the majority typically came with the low manure rate (average 27 bu/acre strip yield increase across sites with the low manure rate and 37 bu/acre increase with the high rate). At several sites the low rate appeared to supply adequate or near-adequate plant-available N, as there was no additional yield response with the high rate. Two sites in 2000 (Hardin and Plymouth) were non-responsive due to high manure application history or drought conditions. Strip yield increases are considered mainly due to manure-N at most sites because of adequate soil test P and K, or because of fertilizer P or K applied across the demonstration area at some sites. Part of the strip yield increases could be due to response to manure P or K at Webster 2000, Clay 2001, Hardin (C-C) 2001, Davis 2002, and Hamilton 2002 where soil tests were optimum or lower. When warm -drying conditions at broadcast application (Clay 2001) or excessively wet spring conditions (Washington 2001, Davis 2002) resulted in apparent N losses, or where corn followed corn, then corn yield was increased with higher manure rates or with additional fertilizer N application (Tables 3 and 4). If yield was improved with the higher manure rate, it was due to a combination of specific manure N rates applied and site conditions. These results with liquid swine manure, and potential effects from loss conditions, are similar to those encountered with N fertilizer.

As expected, late-spring soil nitrate, corn ear leaf greenness, and end-of-season cornstalk nitrate generally increased with manure and fertilizer application rate. The increases in soil nitrate were not consistent between manure and fertilizer application, years, or rate of manure total-N. For example, with manure application late-spring soil nitrate-N values were lower in 2001 than 2000, possibly reflecting effects of cooler and wetter spring conditions. Low late-spring soil nitrate-N levels associated with manure application did not consistently correspond to N deficiency. When manure N or manure plus fertilizer N application was greater than corn need (especially when the rate was excessive), stalk nitrate tests indicated high levels (well above 2,000 ppm). Figures 6-8 represent average corn grain yield, relative corn ear leaf greenness, and end-of-season cornstalk nitrate response to swine manure N and superimposed small plot fertilizer N at five sites where manure was applied to corn rotated with soybean. Relative leaf greenness and grain yield indicated similar corn responsiveness to manure and fertilizer N. Leaf greenness (SPAD readings) will not indicate excess N, but will show deficiency (at approximately < 95% relative SPAD – relative to adequately N fertilized corn greenness); therefore, those readings do not increase once maximum greenness is reached, even with more N. The average manure total-N rate of approximately 150 lb N/acre appeared to supply adequate plant-available N. At approximately 80 lb total manure-N, an additional 40 lb N/acre was needed from fertilizer.

Corn yield response to additional N fertilizer was most consistent in check and low rate manure strips (Table 4). In 2000 and 2001, at only the most N-responsive sites did corn yield increase with additional fertilizer N applied on top of the half-rate manure application, and with only up to 40 lb fertilizer N/acre. In those instances, the amount of manure total-N applied with the low rate plus the additional fertilizer N approximated the amount of fertilizer N required to achieve full yield on the check (no manure) strips. Only at field sites receiving excess rainfall after manure application (denitrification/leaching losses) or warm temperatures at manure application (N volatilization losses of surface-applied manure) did corn yield increase with additional fertilizer N

applied on top of the high manure rate -- no sites in 2000, one site in 2001, and three sites in 2002. These three years of yield data suggest that supplementing swine manure with additional fertilizer N is only necessary when the manure N rate is inadequate to meet specific corn needs or losses reduce N supply. Corn yield response to fertilizer N in the residual manure year (manure applied before soybean and then corn grown the following year) was similar for all prior-year manure rates. This indicates no second-year crop-available manure N supply.

Table 3. Corn grain yield response in field-length strips to liquid swine manure applied in the fall or spring before corn, or before the previous year's soybean crop, 2000-2002.

Site-Year	Swine Manure Application			Statistics <sup>†</sup>	Manure Total Nutrient Application					
	None	Low	High		Low	High	Low	High	Low	High
	- - - - bu/acre - - - -				lb N/acre		lb P <sub>2</sub> O <sub>5</sub> /acre		lb K <sub>2</sub> O/acre	
<u>2000</u>										
Clay	125	156	178	S	77	154	46	91	38	77
Hardin	144	144	145	NS	83	195	100	236	81	191
Plymouth	99	110	99	NS	308	526	199	340	164	280
Washington	136	--	165	S	--	216	--	188	--	180
Webster	122	139	142	S	70	139	48	96	43	86
<u>2001</u>										
Cerro Gordo	121	155	161	S	92	154	58	97	66	111
Clay	106	131	145	S	71	142	35	70	38	77
Hardin	122	141	146	S	115	192	91	152	75	124
Story	148	168	170	S	85	171	73	146	48	96
Washington	89	153	169	S	105	189	74	140	62	112
Wright	119	145	157	S	91	181	65	130	61	122
Cerro Gordo (c-c) <sup>‡</sup>	--	--	--	--	94	211	60	134	66	150
Hardin (c-c) <sup>‡</sup>	131	144	147	S	69	189	55	150	45	122
Floyd (alf-c) <sup>§</sup>	151	163	166	S	103	207	55	110	81	163
Clay (residual) <sup>¶</sup>	84	103	116	S	(114)	(228)	(73)	(146)	(54)	(109)
Webster (residual) <sup>¶</sup>	--	--	--	--	(91)	(182)	(58)	(115)	(59)	(118)
<u>2002</u>										
Davis	43	76	103	S	70	159	48	109	48	109
Hamilton	133	154	174	S	94	188	38	76	64	128
Hardin	170	196	207	S	111	160	59	85	104	150
Washington	144	203	224	S	119	238	82	165	74	147
Hardin (c-c) <sup>‡</sup>	109	151	171	S	67	158	35	84	62	148
Clay (residual) <sup>¶</sup>	--	--	--	--	(100)	(201)	(53)	(105)	(54)	(109)
Washington (residual) <sup>¶</sup>	135	133	135	NS	(114)	(201)	(68)	(125)	(61)	(114)

<sup>†</sup> Statistical significance of yield response to applied manure: S = statistically significant at  $P \leq 0.10$ ; NS = not significant.

<sup>‡</sup> Sites where corn followed corn. Hardin site in 2002 was second year with manure treatment application (same site as 2001).

<sup>§</sup> Site where corn followed alfalfa.

<sup>¶</sup> Sites where manure was applied before the previous-year soybean crop. No manure applied the year corn was grown.

Table 4. Corn grain yield response in superimposed small plots to fertilizer N applied in addition to liquid swine manure total-N rate, 2000-2002.

Site-Year	Swine Manure Application			Statistics <sup>†</sup> (0.10)	Manure Total-N	
	None	Low	High		Low	High
	bu/acre Increase to Additional N <sup>‡</sup>				lb N/acre	
<u>2000</u>						
Webster	29	21	3	S	70	139
Clay	52	13	-3	S	77	154
Hardin	20	11	-8	NS	83	195
Washington	22	--	-2	S	--	216
Plymouth	--	--	--	--	308	526
<u>2001</u>						
Cerro Gordo	25	10	0	S	92	154
Clay	46	31	28	S	71	142
Washington	66	22	-1	S	105	189
Wright	66	27	3	S	91	181
Hardin (c-c) <sup>§</sup>	27	21	1	S	69	189
Cerro Gordo (c-c) <sup>§</sup>	22	5	8	S	94	211
Clay (residual) <sup>¶</sup>	43	46	43	S	(114)	(228)
Webster (residual) <sup>¶</sup>	46	51	40	S	(91)	(182)
<u>2002</u>						
Davis	92	61	29	S	70	159
Hamilton	10	14	20	S	94	188
Washington	87	33	22	S	119	238
Hardin (c-c) <sup>§</sup>	97	66	29	S	67	158
Clay (residual) <sup>¶</sup>	23	10	22	S	(100)	(201)
Washington (residual) <sup>¶</sup>	78	99	91	S	(114)	(201)

<sup>†</sup> Statistical significant response to applied manure total-N and fertilizer N:

S = statistically significant at  $P \leq 0.10$ ; NS = not significant.

<sup>‡</sup> Difference between no fertilizer N applied and the highest one or two rates within each swine manure rate (fertilizer N rates applied at 0, 40, 80, and 120 lb N/acre).

<sup>§</sup> Sites where corn followed corn. Hardin site in 2002 was second year with manure

<sup>¶</sup> Sites where manure was applied before the previous-year soybean crop. No manure applied the year corn was grown.

Corn was very responsive to liquid swine manure application, with large yield increases at responsive sites. Most yield increase was with the low manure rates, with further yield increase from high manure rates at the more N-responsive sites. It was possible to meet corn N requirements solely with liquid swine manure. While it is not possible to exactly discern first-year crop availability, yield and plant N measurements suggest that N in liquid swine manure is highly available to corn in the year of application and appears to support the current suggestion that first-year swine manure N availability is near 100 percent. Results from these three years also confirm that best management of liquid swine manure should consider practices that enhance achieving desired manure rates, minimize potential for N loss, and closely estimate rates of needed N.

### *Yield and Associated Plant Growth Response to Swine Manure and P Fertilizer*

Effects of supplemental P fertilizer on corn yield were tested at 14 locations in 2000-2002 where preliminary soil sampling of small-plot areas indicated “optimum” or lower Bray-1 soil P test levels. Results from 2000 and 2001 sites support ISU fertilizer and manure P recommendations--additional P applied in the form of manure and supplemental P fertilizer may increase early-season corn growth and plant P uptake, but seldom increase grain yield (Appendix Tables 5 and 7) when soil test levels are optimum and higher. The high manure rate did not increase plant growth or P uptake compared with the low manure rate. The P uptake response was mainly due to increased early growth compared with P tissue concentration. These responses were not clearly associated with soil test P levels. Previous research based on P fertilization also showed early growth responses at soil test P levels higher than levels needed to maximize grain yield; however, factors other than P from the manure could explain the responses seen at our field sites. At 2000 and 2001 field sites, application of additional P fertilizer in addition to P supplied by liquid swine manure did not increase corn yield (Appendix Tables).

Effects of manure P on first-year soybean yield were tested at eight locations in 2000-2002 (Table 5). Results from “manure application before soybean” sites concur with results from other studies showing small soybean yield increases and growth response to manure—even when Bray-1 soil P test levels are high. The soybean yield response in high-testing soils was not observed when fertilizer P was applied, also concurring with previous research. The observed yield response to manure is most likely due to complex, poorly understood nutritional and physical factors influenced by manure application (not the manure P itself).

Table 5. Soybean grain yield response in field-length strips to liquid swine manure applied in the fall or spring before soybean crop, 2000-2002.

	Swine Manure Application				Manure Total Nutrient Application					
Site-Year	None	Low	High	Statistics <sup>†</sup>	Low	High	Low	High	Low	High
	- - - - bu/acre - - - -				lb N/acre		lb P <sub>2</sub> O <sub>5</sub> /acre		lb K <sub>2</sub> O/acre	
<u>2000</u>										
Clay	47	48	49	NS	114	228	73	146	54	109
Hardin	54	55	54	NS	83	192	100	232	81	188
Webster	42	43	44	NS	91	182	58	115	59	118
<u>2001</u>										
Clay	47	51	51	S	100	201	53	105	54	109
Washington	49	51	52	S	114	201	68	125	61	114
<u>2002</u>										
Floyd	60	60	61	NS	147	271	103	189	112	207
Hamilton	55	56	55	NS	107	214	53	107	79	158
Washington	58	65	65	S	124	249	95	189	68	137

<sup>†</sup> Statistical significance of yield response to applied manure: S = statistically significant at  $P \leq 0.10$ ; NS = not significant.

Figure 6. Effect of liquid swine manure total-N rate (check, low-, and high-rate applications averaging 0, 80, and 154 lb N/acre, respectively) and additional fertilizer-N on corn grain yield. Yield values are an average of five field sites in 2000 and 2001 where corn followed soybean: 2000 – Webster and Clay County sites; 2001 – Cerro Gordo, Wright, and Clay County sites.

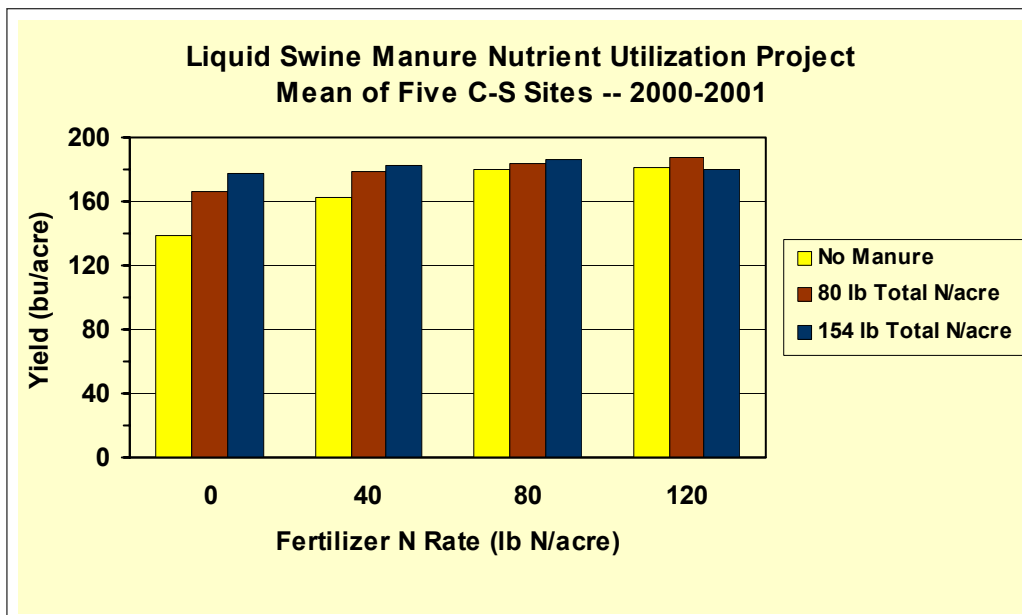


Figure 7. Effect of liquid swine manure total-N rate (check, low-, and high-rate applications averaging 0, 80, and 154 lb N/acre, respectively) and additional fertilizer-N on relative corn ear leaf SPAD chlorophyll meter readings. Relative SPAD data values are an average of five field sites in 2000 and 2001 where corn followed soybean: 2000 – Webster and Clay County sites; 2001 – Cerro Gordo, Wright, and Clay County sites.

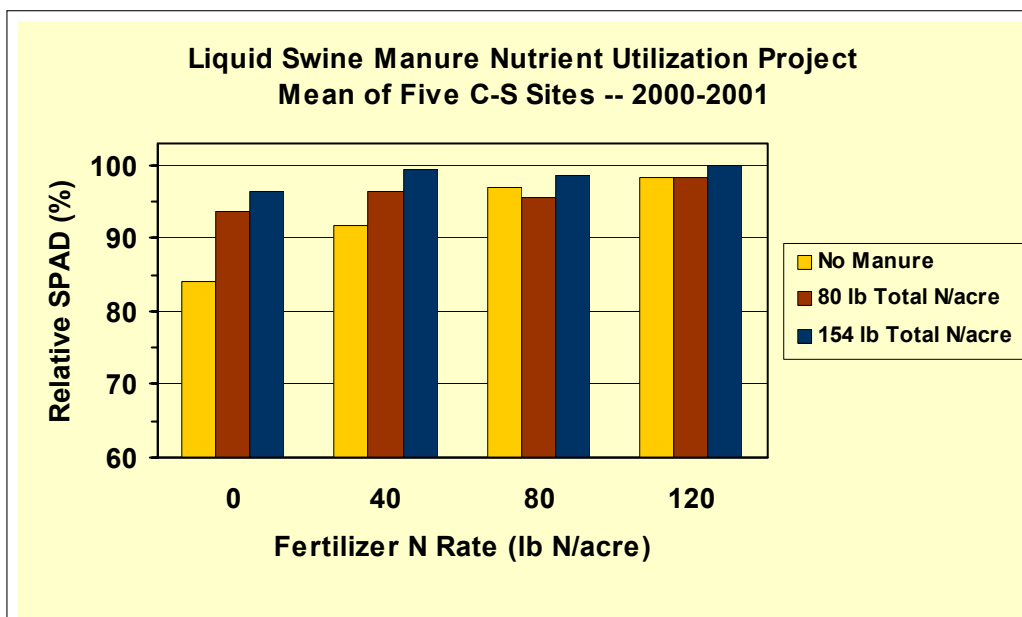
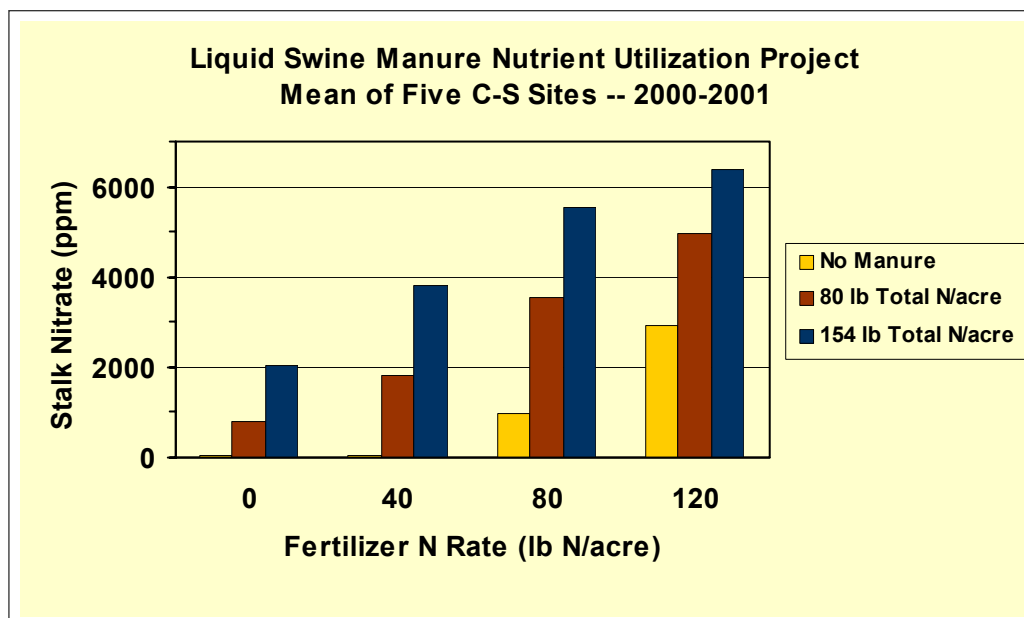


Figure 8. Effect of liquid swine manure total-N rate (check, low-, and high-rate applications averaging 0, 80, and 154 lb N/acre, respectively) and additional fertilizer-N on end-of-season corn stalk nitrate levels. Stalk nitrate data values are an average of five field sites in 2000 and 2001 where corn followed soybean: 2000 – Webster and Clay County sites; 2001 – Cerro Gordo, Wright, and Clay County sites.



#### Swine Manure Effect on Soil P as Measured by Agronomic and Environmental Tests

A component of the demonstration is to evaluate the performance of new environmental soil P tests. Preliminary results from 2000-2001 summarized in Figure 9 suggest that the three agronomic soil P tests (Bray-1, Olsen, and Mehlich-3 methods) and the two environmental soil P tests (iron oxide and water extraction methods) provided similar estimates of manure application effects on post-harvest soil-test P levels. As expected, low manure rates generally produced little change in post-harvest soil-test P levels (as measured by all tests). The tests extracted widely different amounts of P from post-harvest soil samples. Full manure rates increased post-harvest soil-test P levels of all tests. Increases in soil test P provide an indication of the high crop availability of P in liquid swine manure.

As expected, the amount of P extracted by the five soil P tests used varied markedly. However, correlations among all agronomic and environmental P tests were high (Figure 10). The trend lines also reveal no difference in soil P test performance between check and manure-treated soils other than the soil P level. Agronomic and environmental tests seemed similar in estimating P availability in fertilized or manured plots. However, the water environmental P test was less sensitive to changes in soil P caused by manure P application compared with the other tests.

Preliminary results suggest that all soil P tests will adequately evaluate the impact of swine manure on soil P (once amounts of P extracted are considered through appropriate field calibrations). Previous research showed that the agronomic soil P tests are better correlated to yield response from soil nutrient additions. Producers are advised to use the currently used routine soil tests (Bray-1, Olsen, Mehlich-3) for both agronomic and environmental assessments of the impact of manure on soil P.

Figure 9. Effect of liquid swine manure application rate on post-harvest residual soil P as measured by five soil tests (2000 and 2001 data).

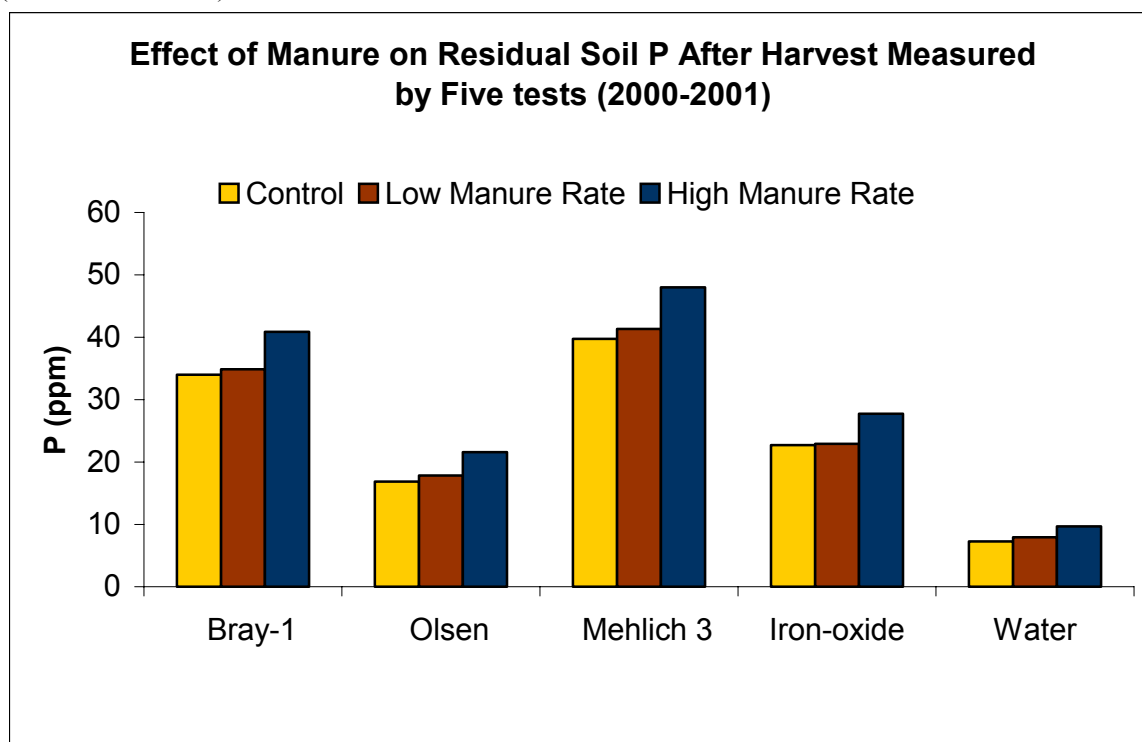
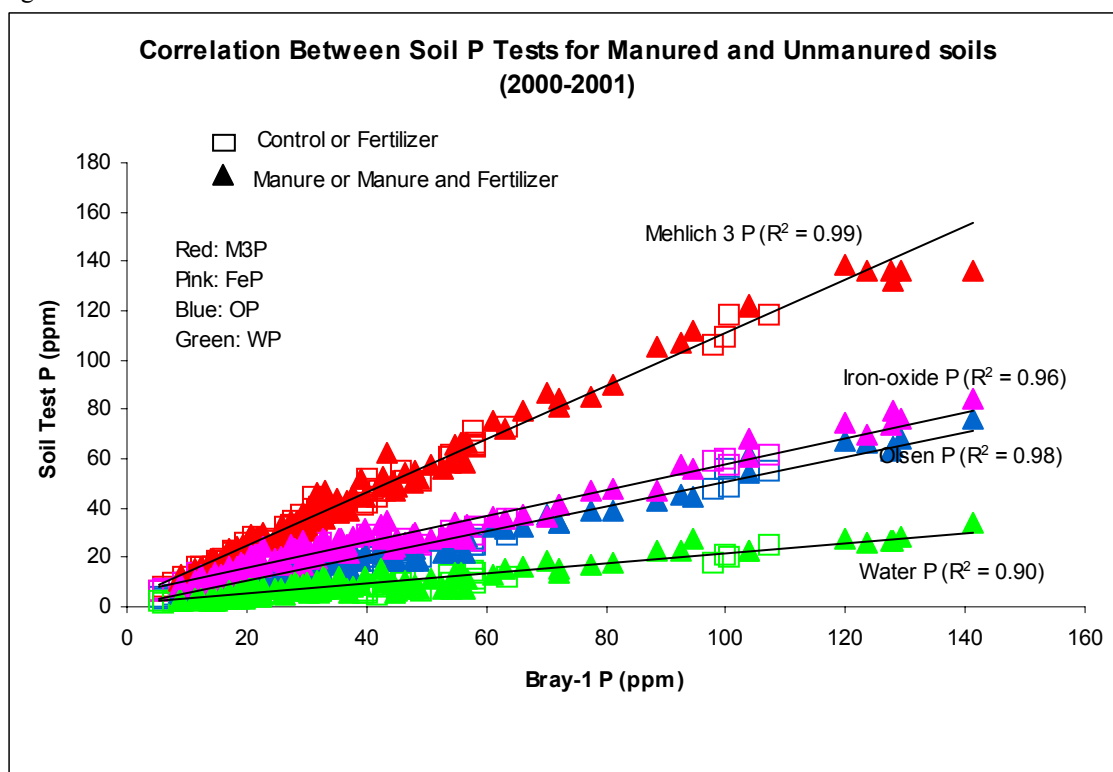


Figure 10. Correlations between soil P tests for manured and unmanured soils.



### ***Project Success In 2000, 2001, and 2002***

Generally the project has achieved its objectives and exceeded expectations since its inception in 2000. The number of demonstration sites has increased each year of the project. The greatest challenge facing the project is identifying P responsive sites; although efforts were successful in locating three sites for 2002 where initial soil test P results were low enough to predict responsiveness to P treatments. Problems identified during establishment (inability to apply low enough rates) and results of the field demonstration at our 2000 Plymouth County site convinced that cooperator to modify his existing manure application strategies by better monitoring total nutrient levels and discontinuing use of his existing manure applicator. Another project success is increased custom applicator awareness of the need for consistent application rate, with greater interest in equipping applicators with flow-rate controllers.

### **Education Component and Outreach Activity:**

The following outreach activities occurred at the project sites in 2000-2002. Field signs indicating the project name, program, cooperating organizations, and cooperating farmer were located at many sites (Figure 11). Information gained from the project is being delivered to farmers, agbusiness, and agency personnel through meetings, conferences, on-going extension education programs and certification programs, fact sheets, newsletters, and web materials.

Figure 11. Project cooperating farmer Rob Stout with promotional signage at Washington County Educational Field Day August 27, 2002.



An important educational multiplier is the extensive use of the project information in extension programs and manure confinement site and custom manure certification programs. From January to March 2001 results of this project were an integrated educational section of the “Nutrient Value of Liquid Manure” component of the statewide confinement site manure applicator certification meetings. Nine hundred sixty eight certified confinement site manure applicators learned about this on-going field demonstration project, and the results, at seventy-seven certification meetings. Project coordinators made presentations integrating results of this project to over six hundred people at ten extension and agribusiness meetings in 2000 and 2001. In 2002 the project was featured in 19 extension and agribusiness meetings, with nearly 300 people attending field days at project sites. Additional outreach and promotion of the project occurs as results are summarized and reported in various popular press articles and through radio interviews. Examples include an article highlighting activities and results of the project in a special Fall 2002 issue of the Iowa Farm Bureau *Spokesman*. The project has also been featured in two newsletter articles written for the Iowa State University “Iowa Manure Matters – Odor and Nutrient Management Newsletter” (ISU Extension Publication EDC-129-17, Vol. 5, Issue 3; and EDC-129-18, Vol. 5, Issue 4). Results of the project were presented in a poster at the 2001 American Society of Agronomy meetings in Charlotte, NC and in two posters at the 2002 American Society of Agronomy meetings in Indianapolis, IN.

### 2000-2002 Field Days

In cooperation with producers, site cooperators, community colleges, and Iowa Department of Agriculture and Land Stewardship and Iowa State University Extension staff multiple field days were conducted in the summer of 2000, 2001, and 2002 at the demonstration sites. Local crop farmers, swine producers, dealers, certified crop advisors (CCA’s), and the general public attended the field days and viewed the demonstration sites. Following is a listing of the field day activities.

<u>2000</u>		<u>2001</u>		<u>2002</u>	
County	Date	County	Date	County	Date
Hardin	July 27	Wright	June 1	Floyd	June 20
Washington	August 9	Wright	July 9	Davis	July 25
Clay	August 31	Cerro Gordo	August 1	Hardin	Aug. 1
Webster	September 12	Hardin	August 2	Wright	Aug. 21
		Clay	August 31	Hamilton	Aug. 22
		Webster	September 13	Washington	Aug. 27
		Wright	September 19		

### Additional Education Components

An important component of this project is to document the process of applying agronomic-based liquid swine manure application rates – especially a method that can successfully result in the application of desired nutrient rates. For most corn production fields, and for requirements of the Department of Natural Resources manure management plans, the rate is based on corn N needs. Once the rate of N to be applied is determined for a particular field, the manure rate is calculated from that N need. This project is documenting that it is possible to accurately set those rates, and accurately achieve application of those rates in the field. It takes effort and proper equipment, but it is possible. The process utilized in the project is this. First, a presample of the liquid manure is collected ahead of manure application. This sample is collected by dipping manure off the top of

the manure in storage (only if total-N is determined), or probing the depth of the storage volume. The sample is collected far enough in advance of planned application for chemical analysis by a laboratory. The results for total-N are compared to historical analyses from the structure to confirm nutrient content. Having a history of analyses is important to confirm current sample results. The presample total-N content is used to set the manure applications for the planned demonstration rates. Once the rate is determined, the applicator is calibrated before application, or a calibrated flow controller is utilized. Once calibrated, the manure rates are applied to the demonstration area. As the manure is applied, multiple manure samples are collected and sent to the lab for chemical analysis. The results of these samples are compared to the pre-sample and for determination of actual applied nutrient rates, and to develop a manure analysis history. In the two years of this project, when this process is followed carefully, the intended nutrient rate is accurately achieved.

A concern identified during this project is the inability of some application equipment (either applicator rate constraints or tractor size) to apply rates low enough for the intended project rates or to meet N rates required in a manure management plan. This issue could be addressed through assistance to producers for purchase of improved application technology such as driven pumps and especially liquid flow controllers and rate adjusting valves. Through the calibration component of this project, this type of application technology has been shown to accurately apply liquid manure at desired rates. Through this project, and educational activities throughout the state, we are convincing producers of the value of liquid swine manure as a nutrient resource and improving the understanding of manure nutrient availability. However, the next step is to improve the capability of producers to apply liquid swine manure at planned agronomic rates.

A success demonstrated in this project has been the application of manure from area swine producers to cooperating crop producer sites (farmers that are not swine producers). This has occurred at multiple demonstration sites in the project and is an important aspect of improved interaction between livestock and crop producers, demonstration and acceptance of manure as a nutrient resource by crop producers, and recognition of the high crop nutrient availability and nutrient value of swine manure. This recognition has important implications for best manure utilization as application to land controlled by crop producers helps with manure management plans, provides improved manure distribution within a geographic area, relieves the pressure on swine producers to apply manure to land that doesn't need additional P, and gets the manure applied to land where crops can best utilize the nutrients.

### **Expected Benefits:**

One, producer recognition of the demonstration project and importance of manure nutrient management as a result of visibility through field signage and field days; two, multiple cooperating and neighboring producers adopt manure application calibration, manure analysis, and manure nutrient best-management practices as a direct result of their participation in the project; and three, enhanced and refined information for manure management plan development and implementation by producers and custom manure applicators across Iowa.

Several project outputs are expected: 1) increased awareness of demonstration activities that reinforce the economic and environmental importance of manure nutrient management; 2) expanded statewide database of plant, soil, and crop yield response to applied swine manure and

estimate of manure N and P availability; 3) improved interpretation of N and P soil tests in manured soils from both agronomic and environmental perspectives that will increase producer confidence in accepting manure as a reliable crop nutrient resource; 4) through a strong producer-field specialist-agbusiness-agency cooperative practice demonstration program, extensive outreach information transfer mechanism to producers and agbusiness via field days and meetings, promotion of experiences learned through the demonstrations, and use of information learned for manure management educational literature; and 5) improved understanding of the importance of manure nutrients in the planning and writing of nutrient plans.

**Project Partners:**

Crop and Livestock Producers  
Heartland Pork  
Iowa State University  
Iowa State University Extension  
Iowa Natural Resources Conservation Service  
Iowa Department of Natural Resources  
Division of Soil Conservation, Iowa Department of Agriculture and Land Stewardship  
Leopold Center for Sustainable Agriculture  
Iowa Central Community College

Collecting an at-application liquid manure sample for nutrient analysis.



Portable scales are used during calibration of liquid swine manure application equipment.



A red tractor is pulling a green Houle sprayer across a field. The sprayer has a large tank and multiple nozzles. The field is covered in dry grass and straw. In the background, there are bare trees and a clear sky.

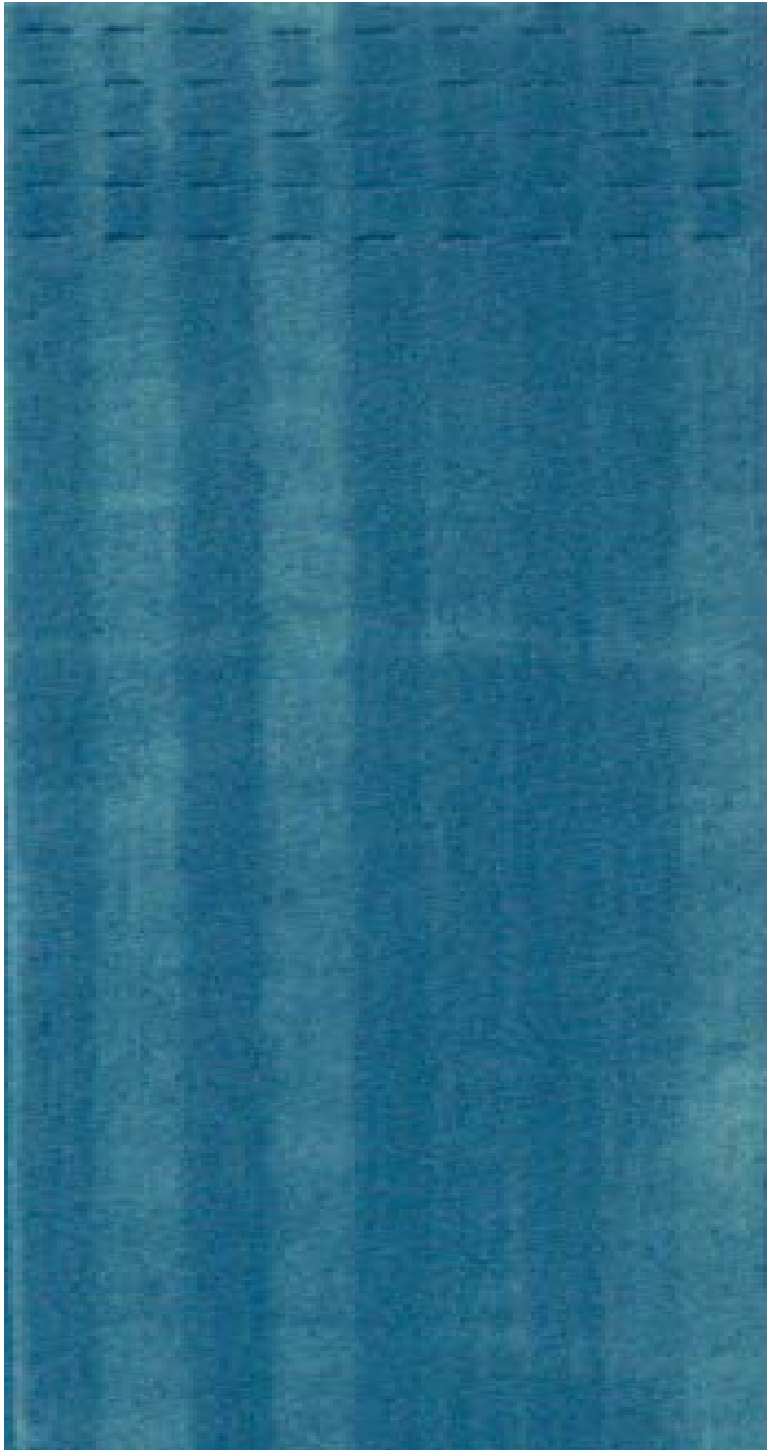
View of field-length replicated treated and untreated strips at the 2001 Wright County (Dows) demonstration site.



Collecting SPAD chlorophyll meter corn “ear leaf greenness” data near R1 corn growth stage.



Late-summer aerial photo of replicated manure strips and superimposed small plots (top of photo) in corn at the 2000 Webster County (Fort Dodge) demonstration site.



Project leader John Sawyer presents data at Floyd County Educational Field Day June 20, 2002.



Project graduate student Sudipta Rakshit (left) and project leader John Sawyer answer questions at Davis County Educational Field Day July 25, 2002.



Project graduate students Sudipta Rakshit (left) and Monica Barbazan (right) present data at Hardin County Educational Field Day August 1, 2002.



Project leader Antonio Mallarino (left) visits with producers at Hardin County Educational Field Day August 1, 2002.



Project leader John Sawyer presents data to field day participants at Washington County Educational Field Day August 27, 2002.

